Faculty of Medicine
School of Medical Sciences

PHAR 3102

Molecular Pharmacology

COURSE OUTLINE

Term 1, 2020

CRICOS Provider Code 00098G

CONTENTS **PAGE**

PHAR3102 Course Information

Molecular Pharmacology (PHAR3102) is a 3rd year Science Course worth six units of credit (6 UOC). The course is usually undertaken as part of a major in Pharmacology in a Bachelor of Science or Bachelor of Medical Sciences and as part of the Medicinal Chemistry Program. This course builds on the information you have already gained in Introductory Pharmacology and Toxicology (PHAR2011).

OBJECTIVES OF THE COURSE

This course will examine the molecular basis of drug action and explore how cutting-edge biotechnology and biomedical research can advance pharmacological knowledge, increasing our understanding of how drugs work. The following areas will be studied in detail: genetic variability in drug action, protein structure-activity relationships, receptor-ligand interactions, signal transduction, biochemical and molecular aspects of receptors and their signalling mechanisms. Research and analytical skills will be developed in practical classes.

COURSE CO-ORDINATOR and LECTURERS

Course Convenor:
Dr Angela Finch
Rm 326 Wallace Wurth Building East ph: 9385 1325

Co-Convenor
Dr Lu Liu
Rm 325 Wallace Wurth Building East ph: 9385 8762

Students wishing to see the course convenors should make an appointment *via* email as our offices are not readily accessible. We will organize to meet you in a convenient location elsewhere in the building.

Lecturers in this course:

Dr Angela Finch	a.finch@unsw.edu.au
Dr Nicole Jones	n.jones@unsw.edu.au
Dr Trevor Lewis	t.lewis@unsw.edu.au
A/Prof Lu Liu	lu.liu@unsw.edu.au
Dr Nicola Smith	n.smith@victorchang.edu.au

Please read this manual/outline in conjunction with the following pages on the School of Medical Sciences website:

- Advice for Students
- Learning Resources

(or see "STUDENTS" tab at medicalsciences.med.unsw.edu.au)

COURSE STRUCTURE and TEACHING STRATEGIES

Learning activities occur on the following days and times:

- Lectures: Monday 10-11am and Tuesday 9-10 am
- Collaborative Learning Session: Tuesday 12 -1 pm or 1 -2 pm*
- Practicals: Friday 10 am-1 pm or 2-5 pm*

  * Once enrolled in one of the two sessions, students cannot change.

Students are expected to attend all scheduled activities for their full duration (2 hours of lectures per week and 4 hours of practical and collaborative learning sessions per week). Students are reminded that UNSW recommends that a 6 units-of-credit course should involve about 150 hours of study and learning activities. The formal learning activities are approximately 68 hours throughout the term and students are expected (and strongly recommended) to do at least the same number of hours of additional study *i.e.* 6 hours per week.

Lectures will provide you with the concepts and theory essential for an understanding of molecular pharmacology. To assist in the development of research and analytical skills practical classes and collaborative learning sessions will be held. These classes allow students to engage in a more interactive form of learning than is possible in the lectures. The skills you will learn in practical classes are relevant to your professional development.

APPROACH TO LEARNING AND TEACHING

The learning and teaching philosophy underpinning this course is centred on student learning and aims to create an environment which interests and challenges students. The teaching is designed to be engaging and relevant in order to prepare students for future careers.

Although the primary source of information for this course is the lecture material, effective learning can be enhanced through self-directed use of other resources such as textbooks and Web based sources. Your practical classes will be directly related to the lectures and it is essential to prepare for practical classes before attendance. It is up to you to ensure you perform well in each part of the course; preparing for classes; completing assignments; studying for exams and seeking assistance to clarify your understanding.

TEXTBOOKS AND OTHER RESOURCES

Due to the cutting-edge nature of this course and the rapid advances made in the field of Molecular Pharmacology, a single primary text which adequately covers the content of this course has not been identified. Therefore, each lecturer will provide you with additional resources to supplement their lecture material. These resources will take the form of textbooks, journal articles or web-based resources. If available, links to the electronic form of these resources will be put on the course Moodle page.

Three textbooks have been identified that together cover the majority of the course content. These texts are also available as online resources from the UNSW library

“Pharmacology in drug discovery: understanding drug response” by T. P. Kenakin.

“Molecular Pharmacology: From DNA to Drug Discovery” by Dickenson, Freeman, Lloyd Mills, Thode, & Sivasubramaniam.

“General and Molecular Pharmacology: Principles of Drug Action” Edited by Francesco Clementi and Guido Fumagalli, will be used as an additional reference text throughout the course.

STUDENT LEARNING OUTCOMES

PHAR3102 will develop those attributes that the Faculty of Science has identified as important for a Science Graduate to attain and the Learning Objectives of the Pharmacology Major.

Pharmacology Major Learning Outcomes

A. Demonstrate an understanding of how drugs/therapeutics are developed, work and are used safely.
B. Critically analyse, interpret and effectively communicate pharmacology data and literature.
C. Design and/or execute experiments or other activities to address pharmacological scenarios.

PHAR3102 Learning Outcomes

On completion of this course students should:

1. be able to describe the genomic regulation of drug action
2. be able to discuss the molecular pharmacology of receptors, channels and enzymes
3. apply their knowledge of molecular biology techniques to the design of an experiment to test a molecular pharmacology hypothesis
4. be able to accurately record experimental data and draw conclusions from experimental data
5. be able to demonstrate their ability to communicate scientific information effectively to a variety of audiences and in a variety of formats.

ASSESSMENT PROCEDURES

- Progress exam (45 min duration) **15%**
- Laboratory notebook **10%**
- Collaborative Learning Activities **20%**
- End of session examination (2 hours duration) **55%**
- Formative Assessment

The *practicals* are provided to support lecture material and practise analytical skills. The practical classes and collaborative learning sessions help you to achieve the learning outcomes 1-5.

In the collaborative learning sessions, students will work in teams to research a technique used in molecular pharmacology. They will build a *wiki* and facilitate a *learning activity* in the collaborative learning session. They will then apply this knowledge in the critical analysis and interpretation of data presented in a journal article. This assessment task will allow you to develop your research, information literacy, critical analysis skills, communication and time management skills, as well as allowing you to demonstrate your ability to work in a team and collaborate successfully (Learning outcomes 1-5).

A penalty will apply for late submissions of assessment tasks (10% per day).

The *progress examination* will be held in the lecture slot on Monday the 16th of March, 10am. This exam will give you feedback on how you are succeeding in the course. The *progress examination* and *end of session examination* will test not only your knowledge of the molecular pharmacology of receptors, channels and enzymes, and molecular techniques used in pharmacology but also your ability to apply the knowledge you have acquired from multiple lectures, collaborative learning sessions and practicals to molecular pharmacology scenarios.

The examinations may be in the format of MCQ, short and long answer questions. The questions will be based on the material covered in the lectures, practical classes and collaborative learning sessions. Material covered prior to the progress exam may be again examined in the final exam. The examinations will address learning outcomes 1-4. The end of session examination will be held during the official examination period.

COURSE EVALUATION AND DEVELOPMENT

Each year feedback is sought from students about the courses offered in the Department of Pharmacology and continual improvements are made based on this feedback. The UNSW myExperience survey is the way in which student feedback is evaluated and significant changes to the course will be communicated to subsequent cohorts of students. Also, a staff-student liaison group will be set up and students will be invited to become class representatives to seek feedback from their colleagues and meet with academic staff to discuss any issues that arise. Based on feedback given in these meetings changes will be implemented during the course and for future years.

Based on the feedback received; in 2009 and 2010: questions were provided to help focus the reading of journal articles for collaborative learning sessions, the proportion of total marks for the final examination was reduced, marks to encourage participation in collaborative learning sessions were given, smaller practical classes and reduction in the length of each experiment to ensure it can be completed within a three hour practical class were implemented; In 2011: the journal club questions are referenced back to the lectures to a greater extent. Dr Finch has worked with Prof Kenakin to develop a textbook that covers some parts of the course; in 2012: formative quizzes have been added to provide more continual feedback and a new textbook was trialled; in 2013: the practical manual was revised. In 2014: the order of the topics covered in the collaborative learning sessions has been changed to better match with the lecture content; in 2015: the unannounced ‘spot quizzes’ are now timetabled quizzes; additional information is provided for each wiki topic to help focus the wiki to the most relevant information; in 2017: the final exam has been reduced from 60% to 55% and the weighting of the journal club component of the collaborative learning sessions has also been increased; in 2018 the number of questions needing to be answered for the journal club has been reduced. In 2019: the lab notebooks will be marked throughout the term, and a peer contribution mark has been added to the learning activity grading. In 2020, more guidance, including online videos and lessons, has been provided to assist in the completion of the lab book and journal club assessment tasks. Online lectures have been modified to have shorter video/activities and the practicals revised to help with time management.

GENERAL INFORMATION

The Department of Pharmacology is part of the School of Medical Sciences and is within the Faculty of Medicine. It is located in the Wallace Wurth building.

Professor Margaret Morris is Head of Department and appointments to meet with her may be made via email (m.morris@unsw.edu.au).

There is an honours program conducted by the School. The Honours program is convened by Dr Cristan Herbert (c.herbert@unsw.edu.au), Ph: 9385 8679. Any students considering an Honours year should discuss the requirements with the convenor.

Postgraduate degrees
The Department of Pharmacology offers students the opportunity to enter the following graduate programs:

Course Work Masters: Masters in Pharmaceutical Medicine. For more information contact Dr Orin Chisholm (o.chisholm@unsw.edu.au)

Research Masters: In Pharmacology. Contact the post-graduate co-ordinators A/Prof Pascal Carrive (p.carrive@unsw.edu.au) and Dr Nicole Jones (n.jones@unsw.edu.au)

Doctorate (***Ph.D)***: In Pharmacology. Contact the post-graduate co-ordinators A/Prof Pascal Carrive (p.carrive@unsw.edu.au) and Dr Nicole Jones (n.jones@unsw.edu.au)

Enrolment and administrative help
The Student Administration Officers are available to help with problems with enrolment and scheduling and should be the first point of contact for administrative problems. They can be contacted via the UNSW Student Portal Web Form.
http://unsw.to/webforms

Attendance Requirements

For details on the Policy on Class Attendance and Absence see Advice for Students and the Policy on Class Attendance and Absence.

Attendance at practical and tutorial classes will be recorded on the class roll at the start of each class. Arrival more than 15 minutes after the start of the class will be recorded as non-attendance. It is your responsibility to ensure that the demonstrator records your attendance and no discussions will be entered into after the completion of the class. Satisfactory completion of the work set for each class is essential.

Practical Classes

The practical class is an opportunity for students to develop graduate attributes by behaving in an ethical, socially responsible and professional manner within the practical class.

Students must take due care with biological and hazardous material and make sure all equipment is left clean and functional. In the interests of safety, special attention should be paid to any precautionary measures recommended in the notes. If any accidents or incidents occur, they should be reported immediately to the demonstrator in charge of the class who will record the incident and recommend what further action is required.

For more details see Advice for Students-Practical Classes

Special Consideration

Please see UNSW-Special Consideration and Student Advice-Special Consideration

Final exam period for Term 1, 2020 is Sat 2 May to Friday 15 May 2020.
Supplementary exam period for Term 1, 2020 is Mon 25 May to Fri 29 May 2020.

If you unavoidably miss the progress exam in PHAR3102, you must lodge an application with UNSW Student Central for special consideration. If your request for consideration is granted an alternative assessment will be organised which may take the form of a supplementary exam or increased weighting of the final exam.

Student Support Services

Details of the available student support services can be found at Student Advice-Student support services.

Appeal Procedures

Details can be found at Student-Advice-Reviews and Appeals

Academic Integrity and Plagiarism

The School of Medical Sciences will not tolerate plagiarism in submitted written work. The University regards this as academic misconduct and imposes severe penalties. Evidence of plagiarism in submitted assignments, etc. will be thoroughly investigated and may be penalized by the award of a score of zero for the assessable work. Flagrant plagiarism will be directly referred to the Division of the Registrar for disciplinary action under UNSW rules.

The UNSW Student Code outlines the standard of conduct expected of students with respect to their academic integrity and plagiarism.
More details of what constitutes plagiarism can be found here

LECTURE and PRACTICAL OUTLINES

The course timetable is appended at the end of these notes

The course is divided into 4 main themes covering the molecular basis of drug action.

- Genomic Regulation of Drug Actions
- Molecular Pharmacology of Receptors, Channels and Enzymes
- Signal Transduction and Modulation
- Receptor Theory

Genomic Regulation of Drug Actions

Pharmacogenetics and Pharmacogenomics

The concept of pharmacogenetics and pharmacogenomics will be covered in these lectures. The types of genetic mutations: single nucleotide polymorphisms; tandem repeat polymorphisms; gene insertion and deletion; gene duplications; alternative splicing and their effects on drug targets will be explored. The influence of genetic background on drug efficacy and the use of pharmacogenomics to individualise therapy will also be covered.

Learning objectives:

- *Define pharmacogenetics and pharmacogenomics*
- *Describe types of common genetic mutations and possible results of each mutation*
- *Give examples to describe the impact of genetic variations on drug efficacy and side effects*
- *Understand how pharmacogenomic technology will lead to individualized therapy*

Pharmacogenetics: Practical

In this practical we will investigate the role polymorphisms of cytochrome *P*450 2D6 play in inter-individual differences in drug metabolism and their contribution to either a lack of efficacy or adverse side effects of drugs. To identify these polymorphisms, we will be using publicly accessible databases, other computer-based techniques and data obtained from PCR.

Learning objectives:

- *Use databases and alignment software to identify single nucleotide polymorphisms in DNA sequences*
- *Describe the effect of genetic variations on drug efficacy and side effects.*

The Regulation of Gene Transcription

This lecture will briefly discuss the process of gene transcription and go on to examine transcription factors in more detail – including their different structures and roles in biological functions such as development, responses to environmental stimuli (e.g. heat or low oxygen), and gene transcription. A number of examples of therapeutic agents that can act by modulating gene transcription – including hormones acting at nuclear receptors, will be discussed.

Learning objectives:

- *Discuss how different types of transcription factors can modulate gene expression.*
- *Briefly describe how biological functions might be regulated by transcription factors.*
- *Describe how drugs or mediators can modulate gene expression via interacting with nuclear receptors.*

Pharmacological Regulation of Gene Expression: Practical

Drug induced changes of gene expression of transcription factors will be examined. Techniques learnt include RNA isolation from fresh tissue explants, RNA quantification, real-time PCR, gel electrophoresis and PCR data analysis. The concepts of primer design will also be introduced.

Learning objectives:

- *Discuss how pharmacological modulation of transcription factors can modulate gene expression.*
- *Design an experiment to test the ability of ligands which target transcription factors to modulate gene expression*
- *Analysis real-time PCR data and draw conclusions from the data*
- *Discuss how real-time PCR works and what types of information it can provide.*

Molecular Pharmacology of Enzymes, Channels and Receptors

Drug Modulation of Enzyme Function

This learning activity will review the basic principles of how drugs modulate enzyme activity including competitive and non-competitive inhibition and the effects of these different modes of inhibition on enzyme kinetics. We will also discuss the ways in which enzyme modulation can be used clinically.

Learning objectives:

- *Define and discuss:*
  - *enzyme active and allosteric sites*
  - *competitive, mixed and non-competitive enzyme inhibitors and their effect on enzyme kinetics*
  - *reversible and non-reversible enzyme inhibition*
- *Discuss with examples the ways in which enzyme modulation can be used clinically*

Voltage-gated ion channels

This lecture introduces the families of voltage-gated channels and identifies the key organs where they have an important role (e.g. nervous system, heart, skeletal muscle). The main structural domains of the voltage-gated ion channels with respect to the crystal structures that are available and how they relate to the experimental evidence for function will be discussed. We will relate these structural domains to common drug actions.

Learning objectives:

- *To know the topology of the different voltage-gated ion channel subunits (sodium, potassium and calcium channels).*
- *To be able to describe the molecular basis for the voltage dependent gating of ion channels.*
- *To be able to describe the simple kinetic mechanism for voltage-gated potassium channel activation.*

Ligand-gated ion channels

This lecture introduces the families of ligand-gated ion channels and the key roles they play, for example in neurotransmission. The main structural domains with respect to the crystal structures available and how they relate to the experimental evidence for function will be discussed. We will discuss how the function of ligand-gated ion channels are altered by common drug actions, and the kinetic mechanism of the actions.

Learning objectives:

- *To know the ligand-gated ion channel families (Purinergic, ionotropic glutamate, nicotinic-like) and the topology of the subunits for each of these families.*

- *To be able to describe the mechanism for ligand-gated ion channel activation, and to apply this mechanism to illustrate:*
    - *competitive and non-competitive inhibition*
    - *partial agonism*
    - *allosteric modulation*

Catalytic Receptors

This lecture introduces the catalytic receptors, covering the five main types of catalytic receptors. The main structural features of catalytic receptors and how they relate to function of these receptors will be examined. The signalling pathways of each main types of catalytic receptors and how signalling is regulated will also be discussed.

Learning objectives:

- *Identify the structural features of the different sub-families of catalytic receptors.*
- *Describe the signalling pathways of each of the catalytic receptor sub-families.*
- *Describe the regulation of catalytic receptor signalling.*

G Protein-Coupled Receptors (GPCRs)

This online lesson will provide an introduction to the six G protein-coupled receptors (GPCR) families. It will explore the structural similarities and diversity between these families. We will compare and contrast the structural features of the N-termini of each GPCRs family and discuss the difference in the sites and modes of ligand binding between each of the families.

Learning objectives:

- *List the GPCR families*
- *Identify representative members of each family*
- *Compare and contrast the structural features of the N-termini of Family A, B, C & F GPCRs*
- *Discuss the difference in the sites and modes of ligand binding between each of the GPCR families*

GPCRs: Role of Structural Motifs in Binding, Activation and Regulation of Signalling

This lecture will take a more detail look at the key structural regions involved in receptor activation and regulation. The role of Receptor Modifying Proteins (RAMPs) in GPCR pharmacology, expression and signalling, and the evidence for GPCR dimerization and the role it plays in receptor pharmacology will also be covered.

Learning objectives:

- *Describe our current understand of the molecular basis for GPCR activation*
- *Compare and contrast the structural features of the N-termini of Family A, B & C GPCRs*
- *Discuss the difference in the sites and modes of ligand binding between each of the GPCR families*
- *Describe the role the intracellular loops and tail play in regulating GPCR function*

Signal Transduction and Modulation

Second Messengers

This lecture will review the types of second messenger molecules. Several examples of second messenger systems, including: the phosphoinositol, Ca^{2+}, cAMP, cGMP and arachidonic acid systems will be covered. The main signal transduction pathways used by GPCRs and catalytic receptors will be introduced in this lecture and the role of second messengers as drug targets will be explored.

Learning objectives:

- *Define second messengers and list major second messenger molecules*
- *Describe main signal transduction pathways used by GPCRs*
- *Provide examples of second messengers as drug targets*

Guanine Nucleotide-Binding Proteins (G proteins)

This lecture will review the members of the G protein superfamily, including large (heterotrimeric) G proteins and small G proteins (the Ras family). It will explore the structural characteristics of this family and the mechanisms of G protein activation and regulation, including the GTPase and GTP switch. G protein dependent signalling pathways will be covered. The role of G proteins in disease will be discussed.

Learning objectives:

- *Describe the structural features of G-proteins*
- *Describe how G-proteins undergo a cycle in which they switch between active and inactive states*
- *Differentiate G protein subtypes based on their signalling profiles*
- *Describe the association between human diseases and G protein mutations*

Gβγ subunits and biophysical studies of receptor coupling

Heterotrimeric G proteins are integral to signal amplification from GPCRs, yet the limelight is usually taken up by the α subunit. In this lecture, we will focus on the often-forgotten role of the βγ subunits in GPCR signalling. We will then discuss the two classical models used to describe how GPCRs interact with G proteins to transduce a signal, critically analysing contemporary studies using resonance energy transfer techniques.

Learning objectives:

- *Identify the different G protein βγ subunits (Gβγ), posttranslational modifications, and cellular expression.*
- *Describe the effectors of Gβγ and how their function is modulated by these subunits.*
- *Discuss the two classical models GPCR:G protein-coupling, namely the pre-coupling model and the collision coupling model.*

Regulation of GPCR Signalling

Mechanisms by which receptor desensitisation occurs, including internalisation, phosphorylation, binding of β-arrestins, and degradation will be covered. The role of homologous and heterologous desensitisation in receptor regulation will be explored. Some of the key enzymes involved in modulation of signalling include; second messenger dependant kinases, G protein receptor kinases, regulators of G protein signalling (RGS) proteins and guanine nucleotide exchange factors (GEFs) that facilitate GDP dissociation, GTPase activating proteins (GAPs) that stimulate GTP hydrolysis and guanine dissociation inhibitors (GDIs). The function and regulation of these enzymes will be covered.

Learning objectives:

- *describe the regulation of the G-protein cycle (on/off switch)*
- *compare and contrast the differences between heterologous and homologous desensitization*
- *describe the steps involved in desensitization*
- *identify the enzymes involved in heterologous and homologous desensitization*

Receptor Internalisation & Alternative Signalling Pathways

Ligand mediated receptor endocytosis and the regulation of this process will be discussed. The role of RAB and ARF proteins and other small GTP-binding proteins that control trafficking and the role of ubiquitylation in the process will be covered. The classification of

desensitisation of GPCRs into Class A and Class B and the role of internalisation in non-G protein mediated receptor signalling will also be discussed.

Learning objectives:

- *List the steps involved in receptor mediated endocytosis, trafficking, recycling and degradation*
- *Identify proteins which regulate the endosomal and lysosomal pathways*
- *Describe the characteristics that define Class A GPCRs vs Class B GPCRs*
- *Describe the role of β-arrestin in membrane trafficking and ubiquitination*
- *Describe the role of β-arrestin in non-G protein mediated signalling by GPCRs*
- *Design an experiment to identify non-G protein mediated signalling by GPCRs*

Receptor Signalling: Practical

This practical will examine the ability of the β_2 adrenergic receptor to activate extracellular signal-regulated kinase (ERK) via G protein dependent and independent signalling pathways. Techniques learnt include protein isolation from cells, protein quantification, Western Blotting, and densitometry data analysis.

Learning objectives:

- *Discuss how pharmacological modulation of GPCRs to induce G protein dependent and independent signalling.*
- *Design an experiment to test the ability of GPCRs to induce G protein dependent and independent signalling.*
- *Analysis Western Blotting data and draw conclusions from the data*

Receptor Theory

Advanced Pharmacodynamics I and II

The pharmacological concept of potency, efficacy, pD_2, pA_2 will be reviewed. The calculation of pD_2 and pA_2 values from concentration-response curves of agonists and antagonists will be covered. Factors affecting pharmacodynamic variability and the role of this variability in drug efficacy and toxicity will be discussed.

Learning objectives:

- *Interpret dose (concentration)-response relationship data and derive pharmacological parameters from experimental data.*
- *Define the terms; affinity, potency, efficacy, ED_{50}, pD_2 and pA_2, as related to dose-response curves and their interpretation'*
- *Describe how spare receptors are identified*
- *Construct a Schild plot for competitive antagonists and calculate a pA_2.*
- *Calculate pA_2 values for insurmountable antagonists using the modified Schild equation.*

Determining Antagonist Potency: Practical

In this computer-aided practical the antagonist potency of mepyramine against histamine-induced contractile responses of guinea-pig ileum will be determined. EC_{50} values will be obtained from concentration-response curves generated by semi-log paper and Prism. The antagonist pA_2 value will be calculated using the Arunklakshana & Schild method.

Learning objectives:

- *Interpret concentration-response relationship data and derive pharmacological parameters from experimental data.*
- *Define the terms; affinity, potency, efficacy, ED_{50}, pD_2 and pA_2, as related to concentration-response curves and their interpretation'*

- *Construct a Schild plot for competitive antagonists and calculate a pA_2.*
- *Calculate pA_2 values for insurmountable antagonists using the modified Schild equation.*

Constitutively Active Receptors and Inverse Agonists

The concept of constitutively active receptors will be discussed in this lecture. Examples of wide-type receptors, naturally occurring receptor mutants, receptor variants created by site-directed mutagenesis, showing constitutive activity will be covered. The concept of inverse agonism and its discovery through molecular pharmacology techniques will be discussed. Examples of inverse agonists will be given and their potential as therapeutics will be discussed.

Learning objectives:

- *Describe the concepts of:*
  - *two-state model of receptor activation.*
  - *constitutively active receptors.*
  - *inverse agonism.*
- *Explain the differences between agonists, antagonists and inverse agonists.*
- *Use examples to describe the potential therapeutic application of inverse agonists.*

Allosteric Modulators

This lecture will cover the principles of receptor allosteric modulation. The concepts of allosteric verses orthosteric binding sites will be explored. The allosteric mechanisms in activation of enzymes, ligand-gated channels and receptor will be covered. The role of allosteric sites as novel drug targets will be explored.

Learning objectives:

- *Describe the concepts of allosteric and orthosteric binding sites.*
- *Discuss the mechanism of action of allosteric modulators.*
- *Discuss advantages that allosteric modulators have over orthosteric ligands as therapeutic drugs.*
- *Describe the methods by which allosteric modulators of GPCRs can be identified.*

Signalling-Bias

Signalling-bias (also called; ligand-directed signalling, functional selectivity, agonist-directed trafficking, biased agonism, or protean agonism) describes the observation that different ligands acting on the same receptor cause different patterns of response. These observations have led to a change in the concept of the receptor as either off or on but rather existing in a spectrum of conformational states each of which gives rise to a different signalling outcome. This lecture will explore these concepts and the influence they have on drug development.

Learning objectives:

- *Describe efficacy as defined by the signalling-bias theory*
- *Provide examples of experimental data that supports the concept of signalling bias*
- *Identify the factors which contribute to the molecular basis of signalling bias*
- *Discuss how ligand binding kinetics could influence signalling bias*
- *Describe the therapeutic consequences of ligand-specific receptor conformations using clinical examples.*

Receptor Theory I: Occupational and Operational models of agonist action

Since the 1920's models have been developed to assist in the understanding of the complex events that occur upon ligand binding to receptor. The first simple model was the two-state model, however with advances in pharmacology (such as molecular pharmacology) this model could no longer explain the results obtained, which led to the development of more complex models; such as the Occupational and Operational models of agonist action. This lecture will

discuss the development of these models and examine specific examples of experimental results which support the receptor states described by these models. The Induction versus Conformational Selection hypotheses of ligand action will also be covered.

Learning objectives:

- *Describe the basis of the occupancy model of agonist action*
- *Describe the basis of the operational model of agonist action*
- *Identify the hypotheses which describe ligand conformational selection and induced fit*
- *Provide examples of experimental data which supports the hypotheses of ligand induced fit and conformational selection*

Receptor Theory II: Ternary Complex Models

This lecture builds on the models covered in the last lecture. As with the development of the operational model from the occupational model, advancement in pharmacological research generated the data that could not be explained by the operational model. This led to the development of more complex models; such as the Ternary Complex Model. This lecture will discuss the development of these models and examine specific examples of experimental results which support the receptor states described by these models

Learning objectives:

- *Give definitions for the factors and constants of the ternary complex models*
- *Identify factors within the ternary complex models that could account for signalling-bias*
- *Describe the experimental evidence that supports the existence of the species found in each of the ternary complex models*
- *Describe what each species in the ternary complex models represent*

Orphan Receptors

Despite all we know about G protein-coupled receptors, as outlined in previous lectures, the majority of GPCRs actually fall into a category called ‘orphans’ because they are yet to be paired with their endogenous ligand. This lecture will look at why orphan GPCRs are important drug discovery targets and explore different scientific approaches for understanding their function in health and disease. The concepts in this lecture will draw heavily from the previous areas covered in the course.

Learning objectives:

- *Define what an orphan G protein-coupled receptor is, outline some of the difficulties with deorphanising GPCRs and list the types of criteria used to officially proclaim an orphan ‘deorphanised’.*
- *Discuss the types of signalling assays used to measure orphan GPCR activity, reflecting on concepts learnt in previous lectures (e.g. constitutive activity, inverse agonism, G protein coupling pathways, second messengers, receptor regulation).*
- *Define a surrogate ligand and discuss methods for discovering surrogate ligands for GPCRs.*

TIMETABLE

Wk	starting	Lecture Monday 10-11 am, Matt C	Lecture Tuesday 9am, Matt C	Collaborative Learning Tuesday 12-2pm BioSci G07	Practical Friday 10-1 & 2-5 WW Lvl 1	Online
1	17/2	Pharmacogenetics/ genomics I (L Liu)	Pharmacogenetics/ genomics II (L Liu)	Microarray/ siRNA	Pharmacogenetics	Introduction to Molecular Pharmacology (lecture)
2	24/2	Nuclear Receptors/Transcription Factors (N Jones)	Voltage Gated Channels (T Lewis)	Journal Club	Pharmacological Regulation of Gene Expression (Part A) (	Enzymes *(Lecture)*
3	2/3	Ligand Gated Channels (T Lewis)	Catalytic Receptors (A Finch)	Genetically Engineered Animals/ Reporter Gene Assays	Pharmacological Regulation of Gene Expression (Part B)	GPCRs: Introduction to the Families *(Lecture)*
4	9/3	GPCRs: Activation Mechanism (A Finch)	Second Messengers (L Liu)	Journal Club	Pharmacological Regulation of Gene Expression (Part C)	
5	16/3	**Progress Exam**	G proteins (L Liu)	Protein Crystallography/Receptor binding assays	Pharmacological Regulation of Gene Expression (Part D)	
6	23/3	What is the role of the βγ subunit? (N. Smith)	Regulation of GPCR Signalling (L Liu)	Journal Club	Receptor Signalling (Part A)	
7	30/3	Receptor Internalisation & Alternative Signalling Pathways (A Finch)	Allosteric Modulators (A Finch)	BRET/ Confocal Microscopy	Receptor Signalling (Part B)	
8	6/4	Constitutive Active Receptors (L Liu)	Advanced Pharmacodynamics (L Liu)	Journal Club	Public Holiday	Advanced Pharmacodynamics II *(Lecture)*
9	13/4	Public Holiday	Operational Model and Selection vs Induction (A Finch)	Calcium signalling/ cAMP Assays	Receptor Signalling (Part C)	Determining Antagonist Potency (Part A) *(practical*
10	20/4	Signalling Bias (A Finch)	Ternary Complex Model (A Finch)	Journal Club	Receptor Signalling (Part D)	
11	27/4	Orphan Receptors (N. Smith)			Determining Antagonist Potency (Part B) **Tuesday 28th April 10am-1pm & 2-5pm**	

ASSESSMENT TASKS

Task	Due Date
Collaborative Learning Session Assessment:	
Part 1a: Molecular Techniques Wiki draft and learning activity plan	10:30 pm the Monday the week prior to learning activity presentation
Part 1b: Molecular Techniques Wiki	10:30 pm the Sunday of the week of scheduled presentation
Part 2: Learning Activity	During assigned collaborative learning session
Part 3a: Journal club notes	Prior to the start of each collaborative learning session where assigned
Part 3b: Evidence of Critical Analysis Skills Development	Friday, 24th April, 5 pm
Open-book Quizzes	In practical class in weeks 2,4,6,9,11
Progress Exam	Monday, 16th March, 10 am
Laboratory Notebook	Monday 10:30 pm weeks 2, 6, 11 and Friday 5 pm week 11
Final Examination	Official exam period

Formative Assessment

The goal of formative assessment is to provide ongoing feedback that you can use to improve your learning. Formative assessment tasks help students identify their strengths and weaknesses and therefore the areas they should focus on.

Open Book Quizzes.
Five times in the term, during a practical class, a 15-minute open-book quiz will be given. This quiz will be a mixture of MCQ and short answer questions. You will be able to use your lecture notes (slides and your handwritten notes) and other notes you have made from textbooks and other additional reading suggested by your lecturers.

Exams

The questions will be based on the material covered in the lectures, practical classes and collaborative learning sessions**.**

Progress examination (15%) will be held in the lecture slot at **10 am on Monday the 16th of March.** This exam will give you feedback on how you are succeeding in the course. This examination consists of two parts (A & B):

- Part A consists of multiple-choice questions
- Part B consists of short answer questions, with choice

Final Examination (55%)
The examination consists of three parts (A, B & C)

- Part A consists of multiple-choice questions.
- Part B consists of short answer questions, with choice
- Part C consists of long answer questions, with choice

Material covered prior to the progress exam may be examined again in the final exam

Laboratory Notebook (10%)

You will be required to keep an electronic laboratory notebook (ELN) for all practical classes in this course. Keeping a laboratory notebook is an important skill for every scientist to develop. Laboratory notebooks are a complete record of all the procedures carried out and data collected for each experiment. Enough detail needs to be recorded so as someone could reproduce your experiment at a later date. A laboratory notebook is a legal document and as such certain conventions and procedures must be followed.

The following information should be recorded in your electronic laboratory notebook for each experiment:

A. To be completed before you come to class:

In your electronic laboratory notebook (ELN) record:

1. Your Rationale and Plan

Rationale: The hypothesis/ aim of the overall experiment should be clearly identified and succinctly stated.

Plan: An experimental plan to address your hypothesis/aim. Only the major steps in the experimental plan should be listed. You can work this out by looking at the headings in methods sections of the laboratory manual. *For example, for the Pharmacological Regulation of Gene Expression and GPCR signalling experiments this would be the major steps for all four weeks.*

2. Experimental Page

On the experimental page for the week record the date using the format YYYYMMDD and a title for this week's experiment.

Aim/Goal: A very brief indication of the goal of this day's work. This is independent of the rationale page in your experimental folders. The Aim can be as simple as 'to stimulate cells and collect samples' but you need one so that the reader can follow your logic.

Preparation: Sometimes you will need to do some calculations before you start the experiment. You should put these calculations here. This could be a photo or scan of working on a piece of paper or a screen shot of a table filled in on the laboratory manual PDF. If there are preparation questions they should be completed and uploaded before the start of your class.

Also record under preparation that you have read and understood the safety summary and note anything you particularly need to be careful of when doing the experiment.

B. To be completed during the class:

Protocol:

- Provide a link to the protocol found in the laboratory manual.
- Note any changes to the protocol.
- Also make sure you note any changes that inadvertently occurred along the way (accidentally incubated for too long, forgot a wash step). *Mistakes happen and no one is penalised for making mistakes but it is really important to document them.*
- If you printed out the protocol and scribbled notes on it in the lab, take a photo of it and upload here.

- Include drug concentration/ amount of protein/drug dilutions etc.
- All experimental conditions need to be recorded. *Screen shots or photos of notepads are fine - don't create more work for yourself!*
- Record what is in each tube and what code you have given each tube.
- Any issues with the experiment should be noted (e.g. ran out of ligand for tube 18).
- Record any calculations you have done

Results: All data collected with correct units, titles and labelled axes on graphs, and titles and labels for all drawings, films and printouts should be uploaded to this section of the page. Also upload all raw data excel files, PRISM files etc

Notes: In this section record anything else you would like to note, be creative or conversational as you like. This could include ideas you have had, questions you want to go and find the answers to, conversations about your work, links to theory being learned in lectures and CLS, hints and tips given by the teaching staff, reflection on how the day went and what you would do differently next time.

Grouped Results: Here you should upload the class data files that you have used, a description of what analysis you have done and then the grouped PRISM file, images of any graphs produced etc.

C. To be completed at the end of the experiment:

Conclusions: Provide a very brief summary of major points illustrated by the data. If the results were not as expected, suggest possible reasons for this. Note if (i) your results support or disprove your hypothesis, (ii) how your findings relate to other studies in the literature and (iii) what would you suggest would be the next step for this research? *Note this section should be brief and to the point <250 words. N.B. This only needs to be done once for multi-week experiments.*

Laboratory Notebooks will be marked the week after the completion of each experiment to provide feedback as you progress through the course. Your demonstrator will also provide feedback each week.

Experiment	Lab Book Due	%
Pharmacogenetics	Monday 24th Feburary10:30pm	1
Pharmacological Regulation of Gene Expression	Monday 23rd March10:30pm	4
GPCR Signalling	Monday 27th April 10:30pm	4
Determining Antagonist Potency	Friday 1st May 5 pm	1

Marking Criteria – Laboratory Notebook

Criteria	***Excellent*** **5**	***Very Good*** **4**	***Good*** **3**	***Needs Improvement*** **2**	***Unacceptable*** **1**	**0**
Rationale _____**/5 x 1**	The hypothesis/ goal/ specific aim of the overall experiment is clearly identified and succinctly stated.	The hypothesis/ goal/ specific aim of the overall experiment is identified.	The hypothesis/ goal/ specific aim of the overall experiment is identified but more or less detail needed.	The hypothesis/ goal/ specific aim of the overall experiment is partially identified, however more details are needed.	The hypothesis/ goal/ specific aim of the overall experiment has not been correctly identified.	The hypothesis/ goal/ specific aim of the overall experiment has not been provided.
Plan _____**/5 x 1**	The major steps in the experimental plan clearly identified.	The major steps in the experimental plan identified	The major steps in the experimental plan identified but more or less detail needed	The major steps in the experimental plan partially identified, with some errors.	The major steps in the experimental plan have not been correctly identified.	No plan provided
Calculations _____**/5 x 2**	Preparation calculations completed prior to class. All calculations are recorded and correct.	Preparation calculations completed prior to class. All calculations are recorded and mostly correct.	Preparation calculations completed prior to class. Most calculations are recorded, some errors present.	Not all preparation calculations completed prior to class. Some calculations not recorded, and/or many errors present.	Not all preparation calculations completed prior to class. Few calculations recorded, and many errors present.	No preparation questions completed prior to class. No record of calculations.
Protocol _____**/5 x 2**	Link to protocol given. All changes noted. All key information recorded.	Link to protocol given. All changes noted. Most key information recorded.	Link to protocol given. Most changes noted. Key information missing in some experiments.	Link to protocol given. Few changes noted. Key information missing in multiple experiments.	Link to protocol not given. No changes noted. Key information missing in most experiments.	No experimental protocol recorded
Data files and analysis _____**/5 x 4**	All data collected are presented. Files are labelled correctly. All analysis performed correctly	All data collected are presented. Most files are labelled correctly. Most analysis performed correctly	Some data not presented. Some files are labelled correctly. Some analysis performed correctly	Some data not presented. A few files are labelled correctly. Many errors in data analysis.	Most of the data collected not presented. Files are not labelled correctly. Data not analysed or significant errors.	No data presented
Presentation _____**/5 x 4**	The data are clearly labelled. Correct units are given. All Safety sheets noted as read, correct date format and exp title provided.	The data are clearly labelled with minor omissions. Minor errors in units given. All Safety sheets noted as read, most dates formatted correctly and exp title provided	Data are clearly labelled but with minor omissions or errors in units given. Most safety sheets noted as read, most dates formatted correctly and exp titles provided.	Some data not labelled. Correct units not used. Some safety sheets noted as read, some dates formatted correctly and exp titles provided.	The data are not labelled. Correct units not used. No record of reading safety sheets, dates not recorded or incorrect format. Exp titles not provided.	No data presented
Conclusions _____**/5 x 6**	Clear and concise conclusions given. Conclusions are valid and linked back to the rationale.	Clear conclusions are given but are not concise. Conclusions are valid and linked back to the rationale	Conclusions are given. Minor errors in conclusions or more links to the rationale needed.	Conclusions are given but need more detail or less detail. Some conclusions are not valid and/or not linked to rationale	Conclusions do not accurately describe the results of the experiment. Poor links to rationale	No conclusions provided

Collaborative Learning Session (CLS) (20%)

Overview

Publishing a scientific paper is the primary way that a scientist contributes new knowledge or methods to the scientific community. Collectively, these journal articles chronicle advances in science and technology. Without this foundation of work—whether a seminal contribution or a simple finding—future experiments would have no context and scientific research could not progress. Thus, understanding the literature is vital to understanding scientific research. It is important to realise that it is not uncommon for scientists not to agree with the interpretation and conclusions that the authors of papers make and that it is important to draw our own conclusion about the data. Unfortunately, in this digital era there are also less than reputable publishers that don't conduct proper peer review and publish articles that are not scientifically sound, we all need to sharpen our critical analysis skills so we can spot these.

To understand scientific literature, however, it is important to know what tools and techniques scientists use to ask and answer questions. Over the course of the term, you will explore several molecular biology techniques that are essential to understanding the scientific papers publish in the area of molecular pharmacology. Each student team will design and lead an exploration of a laboratory technique that is found in the papers to be discussed in each "journal club" collaborative learning session.

The learning objectives of the collaborative learning sessions (CLS) are for you to develop the skills and confidence in interpreting and critically evaluating data presented in scientific articles

Part 1: Make a wiki about the technique

To help your classmates prepare for the activity you will design, your group will write a wiki about the technique that contains the following information:

- **How the technique works.** For example, describe the materials needed or provide an annotated diagram of the important steps involved, or the molecular process that occur during each step of the technique.

- **How the technique is used.** Include a description of what type of information this technique provides and what types of questions can be answered using the technique.

- Two **Hypotheses** that could be tested using this technique and two hypotheses that could not be tested using this technique. Include an explanation of why they can or cannot be tested using this technique.

- **Benefits and limitations of the technique.**

- **References.** List any resources that your group used to develop the fact sheet or in-class activity and highlight other important resources where your classmates can find more information.

The Wiki should not be longer than 1000 words. Each member of the group must write and/or edit a minimum of 100 words. Contributions of less than this will result in a grade of 0/5%. Each member must log onto Moodle themselves; if you use someone else's log-on or work collaboratively outside Moodle your contribution will not be recognised.

Researching your assigned technique

Places to look for general information:

- Textbooks
- Internet: Beware that not all sites will be accurate! Good information can usually be found at university websites, textbook publishers and scientific company websites (*be aware that that are trying to sell their product, so they are putting a positive spin on the information presented*).

Places to look for specific information:

- The library has many books covering molecular biology techniques
- There is a series of books are available in the library and electronically via the library catalogue. This series includes: Current Protocols in Molecular Biology, Current Protocols in Pharmacology, Current Protocols in Nucleic Acid Chemistry, Current Protocols in Human Genetics, Current Protocols in Bioinformatics, Current Protocols in Protein Science.
- Scientific literature (*hint: limit your search to reviews or methods journals*)
- Journal Websites such as: Nature Methods, Molecular Pharmacology, Trends in Pharmaceutical Sciences, Cell, Science Signaling,

Part 2: Design and lead an in-class activity

Each team will work together to design and lead an in-class activity that will:

1. Actively engage your classmates in learning about the technique.
2. Help your classmates determine how well they understand the technique.

The entire activity should take no more than 15 minutes. After the activity, plan to spend 5 minutes to tie everything together and answer any questions your classmates might have. Altogether, you will have 20 minutes of collaborative learning session time, so use it wisely**.**

A lesson plan will be submitted for feedback the week prior to your lesson.
The lesson plan should include a description of the planned activities, and any questions that will be asked plus the answers to the questions.

Some ideas for activities

- **Interpret data from an experiment** that employs the technique. Develop a series of key questions that will encourage discussion about what conclusions can be drawn from those data.

- **Sequence the important steps in the technique.** Diagram each step on a separate sheet of paper. Have groups of students describe what is happening at each step, arrange the diagrams into the correct order, and explain why they ordered the steps in that way.

- **Act out the important steps of the technique.** Provide materials for your classmates to serve as critical molecules, reactions, or other "players" in technique, then have each team use the components to "do an experiment" and answer questions based on their "results"

- **Solve a scenario where the technique is done or used incorrectly** (*e.g.* steps missing or out of order, or incorrect conclusions drawn from an experiment). Have your classmates work together to determine the correct order of the steps, propose more appropriate conclusions (and justify their answers), or answer questions about the scenario.

- **Compare and contrast.** Have classmates compare and contrast your technique with another related technique. Give your classmates a set of scientific questions and have each group decide which technique to use for each and explain their decisions.

Part 3: Critical analysis skills development

Journal Club
A journal article that uses the techniques learnt about the previous week and the questions that will step your thorough interpreting and critically evaluating the data will be posted on Moodle. You need to submit the answers to the starred questions to your collection prior to the start of the collaborative learning session. In the collaborative learning session as a class we will step through interpreting and critically evaluating the data presented in article assigned for journal club.

Collection of evidence of critical analysis skills development
You will make a collection of evidence to show your critical analysis skills development. This collection of work will show your progress over time. The collection should include your answers to the journal club questions. It could also include how well you did in the critical analysis question on the quizzes and how you have applied the skills you have learnt to other assessment tasks or situations.

Evidence of Critical Analysis Skills Development (10%)
You will submit a statement of evidence of critical analysis skills development. This statement should not exceed 500 words. In your statement you should describe your progress and achievements with regard to the activities we have done in the CLS and how your critical analysis skills have developed. As part of your statement you should identify the best journal club analysis you did. This example of your critical analysis skills will be marked. Below is a list of some prompts to get you started on reflecting on your progress and achievements.

- Has your learning trajectory been linear or were there ups and downs?
- What were the challenges and difficult experiences?
- What, how, when did you learn?
- How have the tasks in the CLS help you achieve the learning outcomes of the course?
- How have you applied what you learnt in CLS to other situations?
- What are your strengths and weaknesses with regard to critical analysis skills?
- What areas of further skill development do you need to work on?

TIMELINE (what is due when):

Draft wiki and learning activity on Monday 10:30pm the week before your wiki is due.
The convenor will review your draft of the wiki and a description of your learning activity (and any accompanying visual aids, worksheets etc.) and provide feedback and suggestions for improvement. A document outlining your 'Learning Activity' should be uploaded to Moodle at this time.

Final wiki on the Sunday 10:30pm before your scheduled learning activity
The convenor will open your wiki for viewing by the whole course at this time so that your classmates can study it before the collaborative learning session.

Learning activity during collaborative learning session
- Introduce the activity, give instructions
- Guide classmates in completing the activity
- Wrap-up; tie everything together and answer questions
- Do not give a “lecture” on the topic as the rest of the class will have covered that prior to the class by reading your wiki

What to do on the weeks another team will be presenting:
Study the wiki to familiarise yourself with the technique so that you can participate meaningfully in the planned activity. You should come to class prepared to discuss any of the information found in the wiki and how the technique is used in the paper for discussion in the

next journal club.

Journal Club
You need to submit your answers to the questions to your collection prior to the start of the collaborative learning session. This will form part of your evidence of critical analysis skills development. You should also bring a copy of the paper and your answers to the collaborative learning session.

Collection of evidence of critical analysis skills development
You should work on building this collection throughout the term. To aid in writing your statement of development you can also use this as a place to record moments that significantly enhanced your learning or challenges you faced.

Evidence of Critical Analysis Skills Development (10%)
Your statement of development is due on **Friday, 24th April, 5 pm**. After you have completed the final journal club CLS you will need to go back and look at your collection and select the journal club that shows your best critical analysis and interpretation of the data. You will then write about your progress and achievements with regards to the activities we have done in the CLS and how your critical analysis skills have developed.

Marking Criteria Part 1– Molecular Techniques Wiki

Criteria	*Excellent (>8.5)*	*Very Good (8.4-7.5)*	*Good (7.4-6.5)*	*Needs Improvement (6.4-5.0)*	*Unacceptable (<5.0)*
Completeness **_____/10 x1.5**	The wiki contains all assigned elements and all details necessary to fully explain the technique. Your wiki can stand alone for the readers to use as a comprehensive source of information on the technique.	The wiki contains all assigned elements but lacks a few minor details. Your wiki provides readers with most of what they should know about the technique but could be more comprehensive.	The wiki contains all assigned elements but lacks some details. Your wiki provides readers with most of what they should know about the technique but lacks a key detail.	The wiki contains all assigned elements but lacks important details. Your wiki provides a general overview, but readers would need to look elsewhere to fill in the gaps.	One or more assigned elements are missing or incomplete. Your wiki lacks key information needed to give the reader a basic understanding of the technique.
Accuracy **_____/10 x1.5**	All information included in the wiki is accurate. The reader can confidently rely on the wiki as a source of information about the technique.	The information is accurate except for a few minor errors. The wiki is useful as a resource but may mislead the readers on a few small details.	The information is accurate except for a few minor errors. The wiki is useful as a resource but may mislead the readers with some details.	The information contains several errors. While no significant errors are made, the wiki contains enough errors to detract from its usefulness as a source of information about the technique.	A significant error is made that causes confusion. The reader cannot depend on your work as a reliable source of information about the technique.
Clarity **_____/10 x 1.5**	The wiki is well written and easy to read. All terms are clearly defined, and topics are fully explained. Your writing allows readers to easily understand the meaning of all points presented.	The majority of the wiki is well written and easy to read, but a few minor terms or details are unclear. Your writing allows readers to understand the meaning of all points presented.	The majority of the wiki is well written and easy to read, but some terms or details are unclear. Your writing requires readers to infer your meaning regarding a few details.	Some parts are unclear or poorly written. The lack of clarity in your writing is distracting to readers and causes them to question your meaning, but they can still draw appropriate conclusions with some effort.	Major portions or key details of the wiki are unclear or poorly written. Your writing is unclear enough to cause the reader to misinterpret your meaning, leading to confusion about the technique.
Creativity **_____/10 x 1.5**	The wiki makes optimal use of visual aids or other creative elements (pictures, drawings, flow charts, figures, etc.) to illustrate key points of the technique. Your creativity greatly enhances your wiki as a learning tool and provides additional means for the reader to gain understanding about the technique beyond what is stated in the text.	The wiki makes use of visual aids or other creative elements to illustrate key points of the technique. Your creativity enhances your wiki as a learning tool and allows the reader to gain greater understanding about the technique.	The wiki includes visual aids or other creative elements to illustrate the technique, but they are not original or inclusive of details specific to the technique. The readers gain something from the aids but may have trouble visualizing or fully understanding parts of the technique.	The wiki includes pictures or diagrams, but they do not contribute to the readers' understanding of the technique.	Visual aids or creative elements are not used. The reader does not gain a full sense of the technique from your information sheet.
First draft **_____/10 x 2**	The first draft was complete. No convenor contribution needed to bring wiki up to minimal required standard. Minor corrections needed	The first draft was complete. Minor convenor contribution needed to bring wiki up to minimal required standard. Some corrections required.	The first draft was complete. Some convenor contribution needed to bring wiki up to minimal required standard. Significant corrections required.	The first draft was incomplete. Significant convenor contribution needed to bring wiki up to minimal required standard. Major corrections required.	Large amount of convenor contribution needed to bring wiki up to minimal required standard. Extensive corrections required.
Evidence of Collaboration Writing Process **_____/10 x 1**	Revision history indicates substantial team collaboration. Extensive discussion, drafting, editing, and revision were evident throughout the collaboration.	Revision history indicates team collaboration. Discussion, drafting, editing, and revision were evident throughout the collaboration	Revision history shows some evidence of team collaboration. Some evidence of drafting, editing, writing, and revising in the final product.	Revision history indicates little team collaboration. Very little evidence of a drafting, editing, writing, and revision process	The revision history indicates no team collaboration. No evidence of a drafting, editing, writing, and revision process.
Individual contribution to the wiki **_____/10 x 1**	Contributes extensively to the researching, writing, and editing. Shows appropriate wiki etiquette when editing and respects the work of others	Contributes to the researching, writing, and editing. Shows appropriate wiki etiquette when editing and respects the work of others.	Contributes to the researching, writing or editing. Displays appropriate wiki etiquette most of the time and generally respects the work of others	Provides minimal contribution to the researching, writing and editing. Displays appropriate wiki etiquette some of the time but often fails to respect the work of others	Does not contribute to the researching, writing and editing (<100 words).

Marking Criteria Part 2– Molecular Techniques Learning Activity

Criteria	*Excellent (>8.5)*	*Very Good (8.4-7.5)*	*Good (7.4-6.5)*	*Needs Improvement (6.4-5.0)*	*Unacceptable (<5.0)*
Choice of content _____**/10 x3**	The activity addresses key or difficult aspects of the technique. Your classmates will leave with a deeper understanding or reinforced knowledge of the technique.	The activity addresses an important aspect of the technique. Your classmates will learn about the technique but would benefit more from a more in-depth choice of content.	The activity addresses an important aspect of the technique, but not the most important or difficult aspects. Your classmates will learn something about the technique but would benefit more from a different choice of content.	The activity addresses a minor or easily understood aspect of the technique. This will not help further their understanding of the technique beyond what they could easily grasp on their own.	The activity does not address any important details of the technique or its uses. Your classmates will not learn from it.
Knowledge of the technique _____**/10 x3**	The presenters serve as experts on the technique. The content of the activity is clear and accurate, and the team can provide thorough and accurate answers to all reasonable questions raised by the class. Your classmates can depend on you teach them all they need to know about the technique.	The presenters are knowledgeable about the technique. The content of the activity is clear and accurate. The team can accurately answer most reasonable questions raised by the class without assistance. You can give your classmates a sound knowledge of the technique.	The presenters have some knowledge of the technique. The content of the activity is clear and mostly accurate. The team can answer most reasonable questions raised by the class but requires assistance from the instructor in some cases. You are able to teach your classmates most of what they need to know about the technique.	The presenters know a little more about the technique than their classmates. Some content of the activity is unclear or inaccurate, or the team is only able to answer basic questions raised by their classmates about the technique. Your classmates cannot depend on you to teach them much about the technique.	The presenters do not understand the technique themselves. Much of the content of the activity is inaccurate or vague, or the team cannot answer basic questions about the technique. Your lack of preparation causes confusion for your classmates.
Activity design _____**/10 x3**	The chosen activity engages all members of the class in learning about the technique. The activity is well-designed, creative, and generates useful discussion. Your classmates will gain something from the activity beyond what they would gain from simply reading the information sheet.	The chosen activity engages all members of the class in learning about the technique and generates good discussion. Your classmates will learn from the activity but would benefit from a more creative format.	The chosen activity engages most members of the class in learning about the technique and generates some discussion but lacks originality. Your classmates will learn from the activity, but would benefit from a more engaging format or better planned activity	The chosen activity engages the class in learning about the technique but is not well-designed or does not generate useful discussion. Poor planning reduces the effectiveness of the activity in helping your classmates learn about the technique.	The chosen activity does not engage the class in learning about the technique. Your classmates could learn the information just as well by reading the information sheet.
Team participation (team graded as a whole) _____ **/10 x1**	All members of the presenting team work together to lead the activity and make sure it runs smoothly and all members of the team are willing and able to answer questions about the technique. Everyone contributes equally and works as a team.	All members of the presenting team participate in leading the activity and are willing and able to answer questions about the technique, but all do not contribute equally.	All members of the presenting team participate in leading the activity and can answer questions about the technique, however, the members of the team work independently rather than as a team.	Some members of the presenting team show little effort to participate in leading the activity or are not prepared to answer questions about the technique.	The presenting team does not work together to lead the activity and answer questions. Some members do not participate, or a lack of preparation and communication leads to confusion.
Individual contribution to the learning activity	Determined from Teams Evaluation via Moodle. Teams Evaluation tool asks each team member to assess their own and each other's contribution to the group activity and then scales the group grade up or down for each member of the group to reflect their individual level of contribution. Failure to complete the team evaluation will result in 10% reduction in grade for the learning Activity.				

Marking Criteria Part 3– Evidence of Critical Analysis Skills Development

Criteria	*Excellent (>8.5)*	*Very Good (8.4-7.5)*	*Good (7.4-6.5)*	*Needs Improvement (6.4-5.0)*	*Unacceptable (<5.0)*
Content of the collection **_____/10 x 2**	All journal clubs' answers presented; and additional evidence provided; strongly demonstrates a progressive growth with a variety of evidence.	Collection contains samples of work; ≥ 4 journal clubs' answers presented; demonstrates a progressive growth with a variety of evidence.	Collection contains samples of work; >3 journal clubs' answers presented, and additional evidence provided; demonstrates a progressive growth.	Collection contains samples of work; >3 journal clubs' answers presented, or additional evidence provided; demonstrates some development.	Collection contains limited samples/ examples of work; doesn't demonstrates a progressive growth
Critical analysis Skills (as demonstrated in nominated best work) **_____/10 x 3**	The work strongly demonstrates clear, accurate, understanding of the data. Shows high level critical analysis skills.	The work demonstrates clear, accurate, understanding of the data. Shows high level critical analysis skills.	The work often demonstrates clear, accurate, understanding of the data. Shows developing critical analysis skills.	The work shows some understanding of the data but often misinterprets data presented in paper. Shows developing critical analysis skills.	Superficially evaluates and misinterprets the data presented in the paper. Shows lack of critical analysis skills.
Statement of development **_____/10 x 4**	Provides an in-depth insightful analysis of the learning experience; detailed description of analytical skills development trajectory; diverse examples are used throughout to support claims of development	Provides an insightful analysis of the learning experience; describes analytical skills development trajectory; examples are used throughout to support claims of development	Provides an analysis of the learning experience; describes analytical skills development trajectory; Some examples are used to support claims of development	Provides an analysis of the learning experience but is vague and/or unclear; poorly describes analytical skills development trajectory; examples are not used consistently to support claims of development	Provides a description of the learning experience but lacks personal insight; doesn't describes analytical skills development trajectory; no examples provided to show development of skills
Presentation **_____ /10 x 1**	Writing is clear, concise, and well organized with excellent sentence /paragraph structure. Thoughts are expressed in a coherent and logical manner. There are no spelling and grammar errors	Writing is clear and well organized with excellent sentence /paragraph structure. Thoughts are expressed in a coherent and logical manner. There are a few spelling and/or grammar errors	Writing is mostly clear and well organized with good sentence/paragraph structure. Thoughts are expressed in a logical manner. There are a few spelling and/or grammar errors.	Writing is unclear. Thoughts are not expressed in a logical manner. There are many spelling and/or grammar errors	Writing is unclear and disorganized. There are numerous spelling and/or grammar errors.